In order to estimate the strength of structural parts it is essential to be in possession of data regarding their fatigue resistance.

Mass tests on full-scale construction elements in order to estimate their mechanical properties and statistical scatter are usually very tedious. There is also the problem of having these data available at the design stage.

In this paper we shall present an analysis of the fatigue characteristics of light alloys obtained by testing laboratory samples, and shall consider the possibility of using these in order to estimate the strength of the actual parts with due allowance for the statistical similarity criterion of fatigue failure [1, 2].

An analysis of many results of fatigue tests on workable aluminum alloys enabled us to construct a single (universal or unique) fatigue curve for these materials in coordinates of $\sigma - \log N$ ($\sigma$ is the ratio of the amplitude of the acting stress to the fatigue limit $\sigma_{\text{L}}$ on a base of $10^7$ cycles, $\sigma = \sigma / \sigma_{\text{L}}$) [3].

The equation of the single fatigue curve has the form

$$\bar{\sigma} = \bar{\sigma}_{-1} + B \log (N + N_1) \cdots$$ (1)

where $\bar{\sigma}_{-1}$, $B$, $N_1$, $\alpha$ are parameters.

Here the parameter $\bar{\sigma}_{-1}$ constitutes the ratio of the fatigue limit for $N = \infty$ to that on a base of $10^7$ cycles. In order to estimate expression (1) we analyzed 70 fatigue curves plotted from the results of bending tests (with rotation) carried out on samples of 12 alloys (V95, D16, AV, AD33, etc.), 6 to 10 mm in diameter.

The ordinates of the fatigue curves for individual alloys deviated from the average curves in the majority of cases by less than 5 to 7%.

In absolute values Eq. (1) may be written

$$\sigma = \sigma_{-1} + b \log (N + N_1) \cdots$$ (2)

or

$$N = \exp \left[ 2.3 \left( \frac{b}{\sigma - \sigma_{-1}} \right)^{1/\alpha} \right] - N_1.$$

where $b = B\sigma_{-1}$.

Of all known equations of fatigue curves, only the Weibull equation agrees satisfactorily with the unique curve.
Fig. 2. Unique fatigue curve in relative coordinates for the alloy AV under stationary loading [1] d = 40 mm, $\alpha_\sigma = 1.00$; [2] d = 16 mm, $\alpha_\sigma = 1.00$; [3] d = 8 mm, $\alpha_\sigma = 1.00$; [4] d = 8 mm, $\alpha_\sigma = 1.45$; [5] d = 8 mm, $\alpha_\sigma = 1.68$; [6] d = 8 mm, $\alpha_\sigma = 2.27$; [14] full-scale element $\alpha_\sigma = 1.00$] and programed loading [7] d = 40 mm, $\alpha_\sigma = 1.00$; [8, 11, 12, 13] d = 8 mm, $\alpha_\sigma = 1.00$; [9] d = 8 mm, $\alpha_\sigma = 1.45$; [10] d = 8 mm, $\alpha_\sigma = 2.27$; [15] full-scale element $\alpha_\sigma = 1.00$].

Fig. 3. Mean square deviation of the fatigue-life logarithms as a function of the average fatigue-life logarithm for AV alloy [1] stationary loading, 2) programed loading].

Analysis of experimental data showed that the unique fatigue curve was only described by equations containing the parameter $\sigma_{\text{max}} \alpha$, i.e., provision was made for the existence of an unlimited fatigue limit of worked aluminum alloys.

In order to evaluate the possibility of using the concept of the unique fatigue curve for designing structural parts, we analyzed experimental data obtained by applying bending tests (with rotation) at constant and alternating stress amplitudes to smooth and notched samples of AV alloy with various diameters d. Programed tests were carried out at various stress levels, a similarity conversion being made for the stresses in the blocks of programed loading (indicated in Fig. 1 in relative coordinates) in order to represent the service spectra.

The results of the tests are shown in Fig. 2, where in the case of programed loading $\bar{\sigma}$ is the ratio of the maximum stresses of the blocks of programed loading respectively corresponding to the specified fatigue life and a fatigue life of $10^7$ cycles (i.e., the secondary fatigue limit for this number of cycles).

The parameters of the fatigue-curve equation have the following values: $\bar{\sigma}_{\text{max}} = 0.47$; $B = 38.0$; $\alpha = 2.1$; $N_1 \approx (1-5) \cdot 10^3$.

It follows from the graph that the results of the tests are excellently approximated by the unique curve (discrepancies in the ordinates no greater than 5%).

The use of the unique curve greatly simplifies the construction of fatigue curves for samples with different constructional parameters. Thus, if we know the parameters of the unique fatigue curve, then in order to determine the fatigue-curve parameters for samples of a specified alloy in absolute magnitude it is sufficient to test a group of samples at a single stress level in order to determine the position of the curve on the $\sigma$ and N axes. The number of samples should be chosen with due allowance for the required accuracy of estimating the limiting amplitudes of the stresses for the specified bases of the tests [4].

From the results of these tests we establish the average number of cycles $N$ at a stress $\sigma$, which enables us to use (1) in order to determine the fatigue limit $\sigma_{\text{L}}$ on the basis of $10^7$ cycles and also the parameters $b$ of Eqs. (2) and (3).

The spread (scatter) in the fatigue properties of alloys is usually estimated in terms of the mean square deviation of the logarithms of the fatigue life $S_{\text{log}}N$, the mean square deviation of the limited fatigue